University of Al-Mustaqbal
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Medical Laser Applications

Third Stage

Lec 3

Laser eye surgery

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1. Introduction

A. What is Laser Eye Surgery?

- Definition: A medical procedure that uses lasers to reshape the cornea to improve vision.
- Applications: Treats refractive errors such as myopia (nearsightedness), hyperopia (farsightedness), and astigmatism.
- Common techniques: LASIK (Laser-Assisted In Situ Keratomileusis), PRK (Photorefractive Keratectomy), and SMILE (Small Incision Lenticule Extraction).

B. Relevance to Physics

- Role of laser-tissue interactions.
- Precision optics and wavefront-guided treatments.
- Application of principles like energy transfer, wave propagation, and material ablation.

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2. Basics of Vision and Refractive Errors

A. The Human Eye as an Optical System

- Cornea and lens: Focusing light onto the retina.
- Refractive index differences in the eye's components.

B. Refractive Errors

- Myopia: Light focuses before the retina.
- Hyperopia: Light focuses behind the retina.
- Astigmatism: Uneven focusing due to an irregular corneal shape.

C. Goal of Laser Surgery

- Reshape the cornea to correct light focusing.

3. Physics of Lasers

A. **Laser Fundamentals**

- **Definition**: Light Amplification by Stimulated Emission of Radiation.
- Coherence, monochromaticity, and collimation properties.
- Energy concentration for precise tissue interactions.

B. **Types of Lasers Used**

- **Excimer Laser**: Ultraviolet (UV) light (193 nm) for ablation.
  - Precise removal of corneal tissue with minimal heat transfer.
- **Femtosecond Laser**: Infrared light for creating corneal flaps.
  - Produces short pulses with extremely high intensity.

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4. Laser-Tissue Interaction

A. **Mechanisms of Action**

- **Photochemical Ablation**: UV photons break molecular bonds in the corneal tissue.
- No thermal damage due to short pulse duration and low penetration depth.
- Accuracy: Ablation depth of approximately 0.25 micrometers per pulse.

B. **Precision and Control**

- Wavefront analysis to guide treatment.
- Importance of beam shaping and spot size control.

C. **Thermal Effects and Safety**

- Avoidance of collateral damage.
- Cooling systems to maintain corneal integrity.

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5. Laser Eye Surgery Techniques

A. **LASIK**

- Steps: Corneal flap creation (femtosecond laser) → Excimer laser reshaping → Flap repositioning.
- Recovery: Rapid visual improvement with minimal discomfort.

B. **PRK**

- Steps: Removal of the corneal epithelium → Excimer laser reshaping.
- Recovery: Longer healing time but avoids flap complications.

PRK stands for **Photo Refractive Keratectomy**.
It is a type of refractive eye surgery used to correct vision problems like :

- **Myopia (nearsightedness)**
- **Hyperopia (farsightedness)**
- **Astigmatism**

PRK reshapes the cornea using an excimer laser, allowing light entering the eye to focus correctly on the retina for improved vision.

Unlike **LASIK**, **PRK** does not involve creating a corneal flap, making it a good option for patients with thinner corneas or those at higher risk for flap complications.

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6. Physics Challenges and Advancements

A. **Wavefront-Guided Surgery**

- Measures and corrects higher-order aberrations for sharper vision.
- Relies on precise optical imaging techniques.

B. **Future Developments**

- Adaptive optics and real-time imaging.
- Integration of AI for improved surgical planning and outcomes.

7. Risks and Limitations

A. **Common Side Effects**

- Dry eyes, glare, and halos.

B. **Limitations**

- Not suitable for individuals with certain eye conditions (e.g., thin corneas).

C. **Role of Physics**

- Advances in laser technology and imaging to minimize risks.

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8. Summary

A. Laser eye surgery is a remarkable application of physics in medicine.

B. Involves advanced understanding of optics, laser-matter interactions, and wavefront technology.

C. Ongoing developments continue to enhance precision and safety.

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9. Discussion and Questions

- How does laser wavelength affect tissue interaction?
- What are the key challenges in wavefront-guided laser correction?

Discussion

1. **What is the primary purpose of laser eye surgery?**
   A. To replace the cornea
   B. To reshape the cornea and correct refractive errors
   C. To treat cataracts
   D. To enhance color perception
   E. To diagnose eye diseases
   Correct Answer: B
2. **Which of the following is not a refractive error treated by laser eyesurgery?**
   A. Myopia
   B. Hyperopia
   C. Glaucoma
   D. Astigmatism
   E. None of the above
   Correct Answer: C
3. **What does LASIK stand for?**
   A. Laser-Assisted In Situ Keratomileusis
   B. Laser-Assisted Corneal Reshaping
   C. Light Amplification Surgery for Keratoplasty
   D. Laser-Assisted Interstitial Keratoplasty
   E. Light Amplification by Stimulated Keratomileusis
   Correct Answer: A
4. **Which property of lasers ensures precise tissue interaction?**
   A. Coherence
   B. Randomness
   C. Thermal diffusion
   D. Broad wavelength spectrum
   E. Low energy density
   Correct Answer: A

5. **What is the wavelength of the excimer laser used in laser eye surgery?**

   A. 532 nm

   B. 355 nm

   C. 193 nm

   D. 1064 nm

   E. 800 nm

   Correct Answer: C

6. **What does PRK involve that makes it different from LASIK?**

   A. Creation of a corneal flap

   B. Removal of the corneal epithelium

   C. Use of femtosecond lasers

   D. Shorter recovery time

   E. Reshaping the lens

   Correct Answer: B

7. **What mechanism does the excimer laser use to reshape the cornea?**

   A. Thermal ablation

   B. Photochemical ablation

   C. Ionization

   D. Radiation therapy

   E. Electromagnetic induction

   Correct Answer: B

8. **Why is PRK preferred for patients with thin corneas?**

   A. It uses femtosecond lasers exclusively

   B. It avoids the need for creating a corneal flap

   C. It has a shorter recovery period

   D. It does not require anesthesia

   E. It requires fewer lasers

   Correct Answer: B

9. **Which component of the eye is primarily reshaped during laser eye surgery?**

   A. Retina

   B. Lens

   C. Cornea

   D. Optic nerve

   E. Iris

   Correct Answer: C

10. **What role does wavefront-guided surgery play in laser eye surgery?**

    A. Improves blood flow to the eye

    B. Corrects higher-order aberrations for sharper vision

    C. Reduces recovery time significantly

    D. Allows for flap-free procedures

    E. Uses thermal imaging for precision

    Correct Answer: B

11. **What is the primary energy transfer process in laser-tissue interaction during surgery?**

    A. Reflection

    B. Absorption and ablation

    C. Refraction

    D. Thermal conduction

    E. Scattering

    Correct Answer: B

12. **What ensures minimal thermal damage during laser eye surgery?**

    A. Continuous laser beams

    B. Short pulse duration and cooling systems

    C. High penetration depth

    D. Use of infrared lasers

    E. Low-intensity laser beams

    Correct Answer: B

13. **What is the primary purpose of the femtosecond laser in LASIK?**

A. Reshaping the lens

B. Creating the corneal flap

C. Ablating corneal tissue

D. Analyzing wavefront aberrations

E. Cooling the cornea

Correct Answer: B

14. **Which technique has a longer healing time but avoids flap complications?**

A. LASIK

B. PRK

C. SMILE

D. Cataract surgery

E. Wavefront-guided surgery

Correct Answer: B

15. **Which type of refractive error occurs when light focuses behind the retina?**

A. Myopia

B. Hyperopia

C. Astigmatism

D. Presbyopia

E. None of the above

Correct Answer: B

16. **What is the approximate ablation depth of an excimer laser pulse?**

A. 0.1 micrometers

B. 0.25 micrometers

C. 1 micrometer

D. 2 micrometers

E. 5 micrometers

Correct Answer: B

17. **Which type of laser emits ultraviolet light at 193 nm?**

A. Excimer laser

B. Femtosecond laser

C. CO_2 laser

D. Argon laser

E. Nd:YAG laser

Correct Answer: A

18. **What is a common side effect of laser eye surgery?**

A. Increased myopia

B. Dry eyes

C. Detached retina

D. Iris damage

E. Corneal infection

Correct Answer: B

19. **Which principle of physics helps achieve precise optical imaging in wavefront-guided surgery?**

A. Diffraction

B. Reflection

C. Wave propagation

D. Polarization

E. Dispersion

Correct Answer: C

20. **What technology minimizes the risks of laser eye surgery?**

A. Infrared scanning

B. AI and adaptive optics

C. Thermal imaging

D. Manual adjustments

E. UV radiation shields

Correct Answer: B

21. **What does SMILE stand for?**

A. Small Incision Lenticule Extraction

B. Sub-Minimal Intraocular Lens Extraction

C. Small Mechanical Incision Laser Eye surgery

D. Selective Minimal Invasive Laser Enhancement

E. Simplified Method for Improved Lens Extraction

Correct Answer: A

22. **What is the primary goal of reshaping the cornea?**

A. To change the eye's color

B. To focus light correctly onto the retina

C. To remove cataracts

D. To strengthen the corneal tissue

E. To reduce eye strain

Correct Answer: B

23. **Which of the following is NOT a feature of lasers used in surgery?**

A. Coherence

B. Collimation

C. Monochromaticity

D. High scattering

E. Precision energy delivery

Correct Answer: D

24. **What is the main advantage of wavefront-guided surgery?**

A. Faster healing time

B. Correction of higher-order aberrations

C. Elimination of all refractive errors

D. Reduced need for follow-up surgery

E. Completely painless procedure

Correct Answer: B

25. **What ensures safety during laser-tissue interaction?**

A. Beam shaping

B. Spot size control

C. Cooling systems

D. All of the above

E. None of the above

Correct Answer: D